WARMING UP

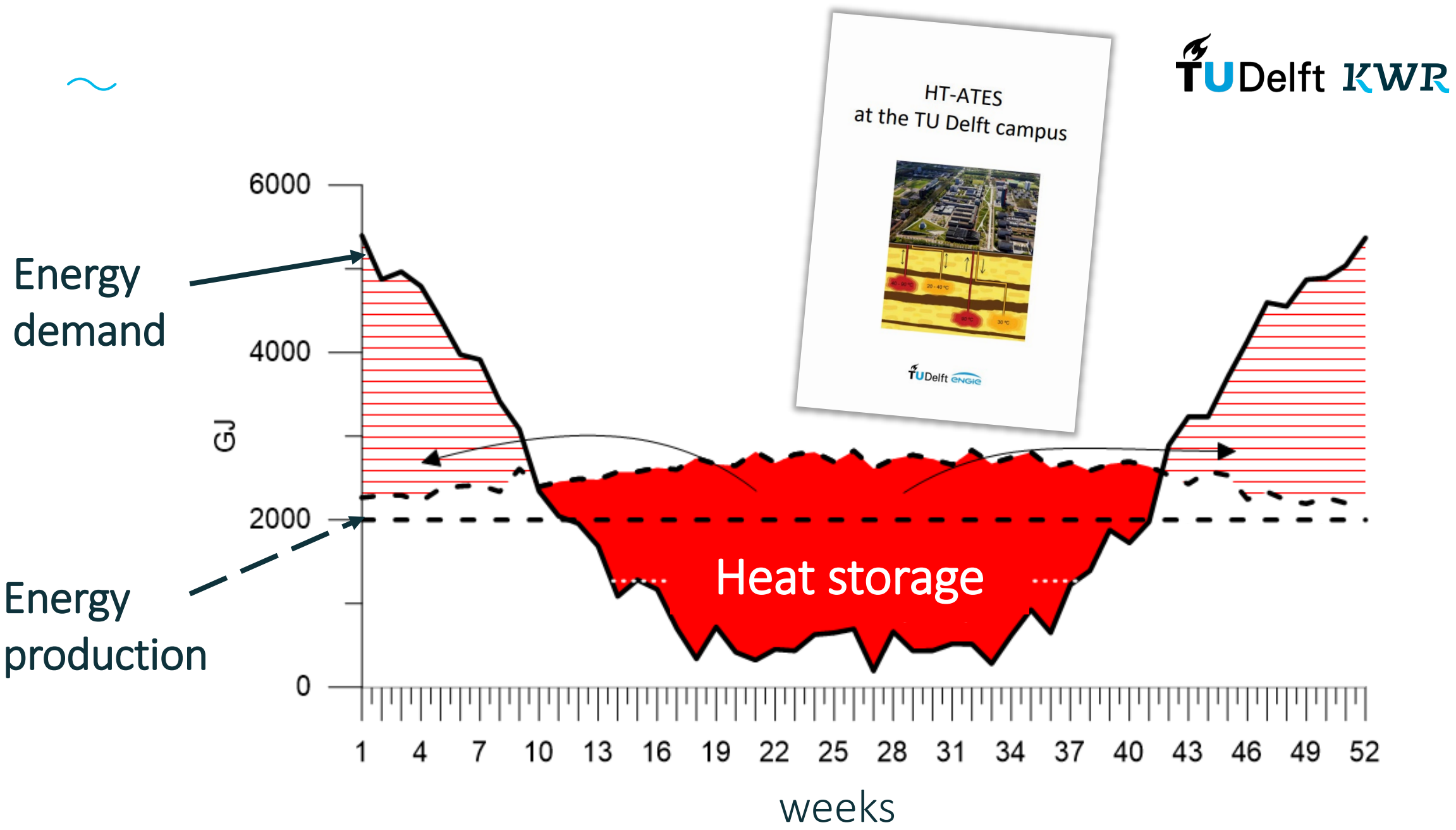
7 March 2023

# Efficient and sustainable subsurface heat storage systems

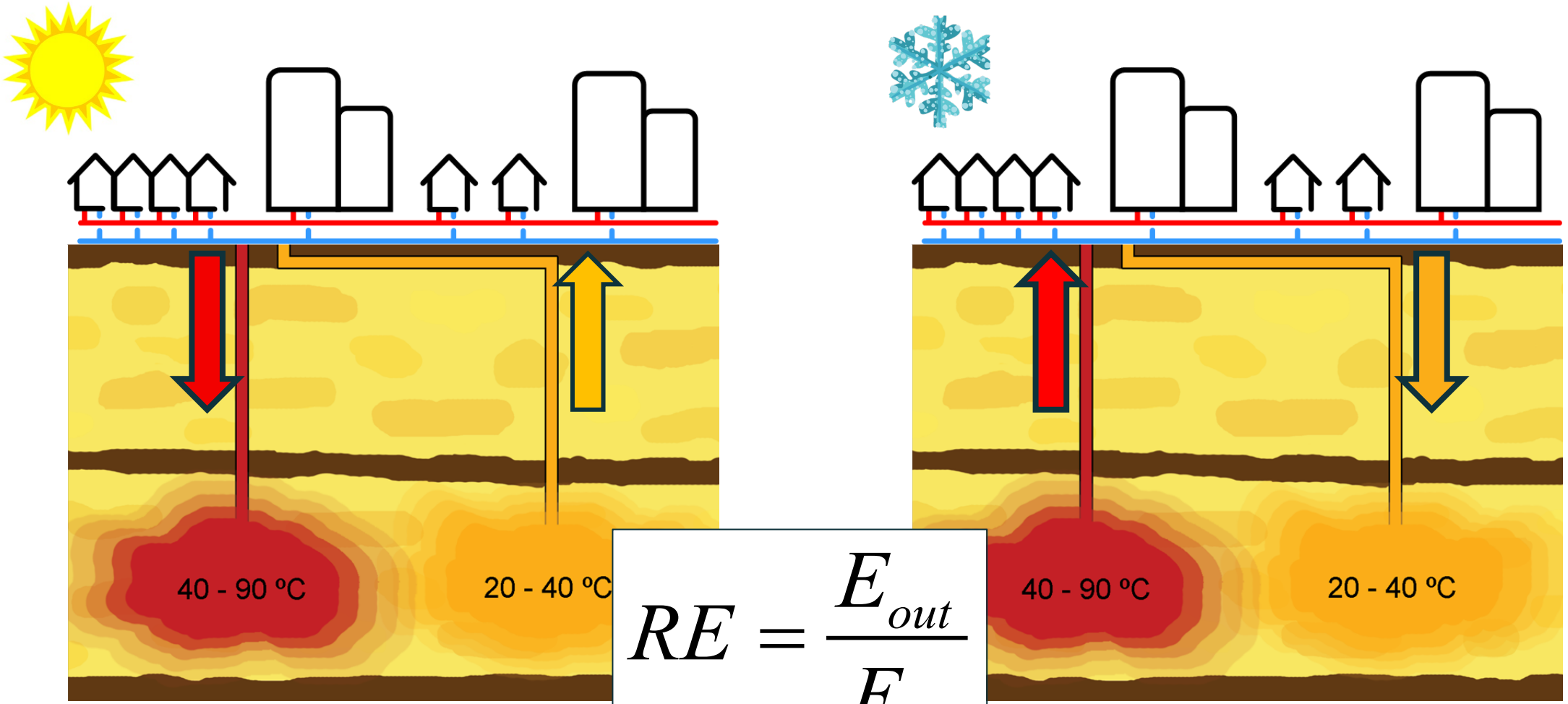
*insight and lessons learned from the WarmingUP project*

KWR TU Delft

**Stijn Beernink,** Martin Bloemendal, Niels Hartog, Phil Vardon, Auke Barnhoorn


HT-ATES
at the TU Delft campus
Energy demand
Energy production
Heat storage
6000
4000
2000
0
GJ
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52
weeks

# High Temperature Aquifer Thermal Energy Storage

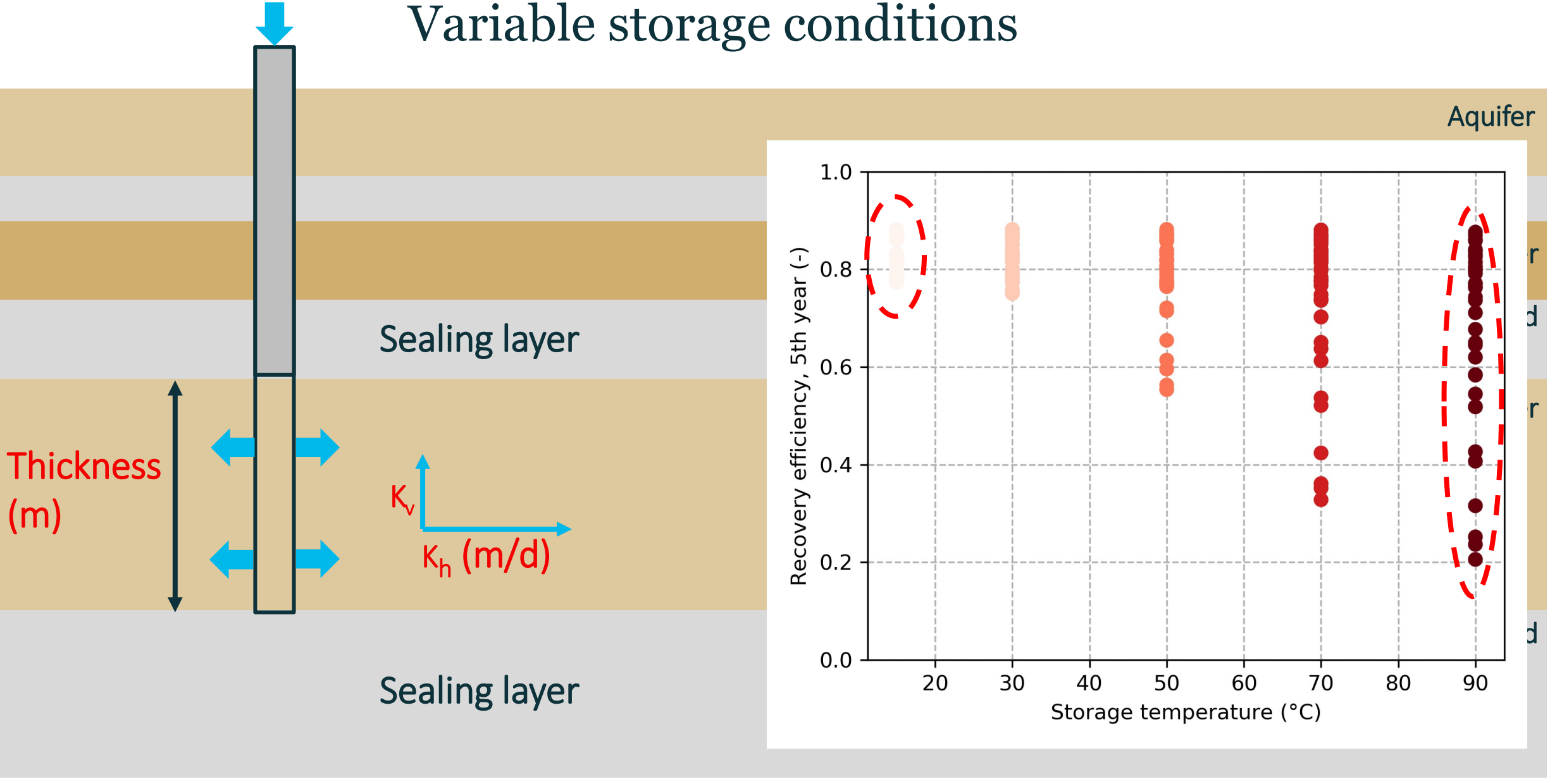



$$RE = \frac{E_{out}}{E_{in}}$$

Storage volume?

Storage temperature?

# Variable storage conditions

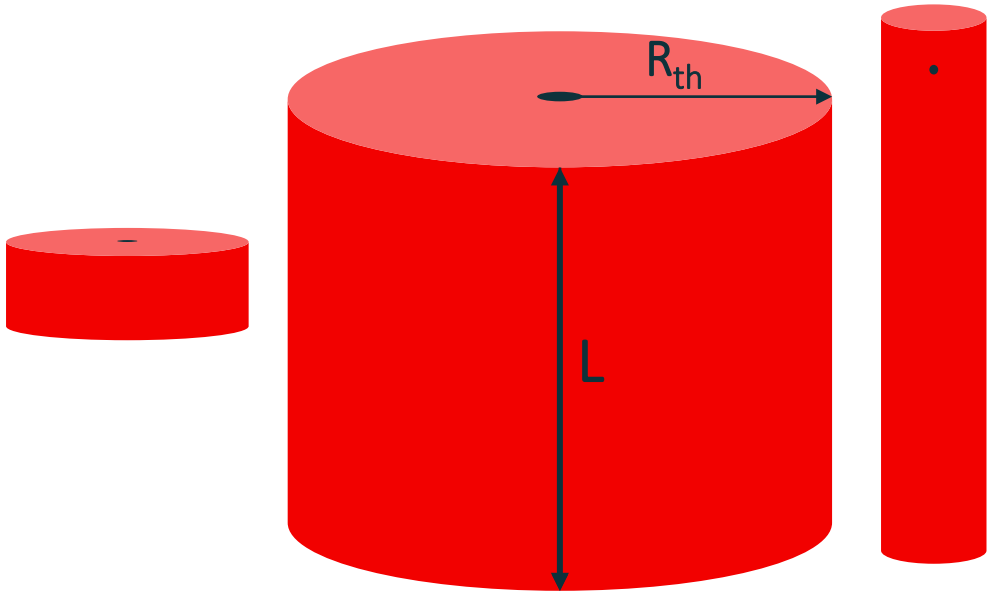


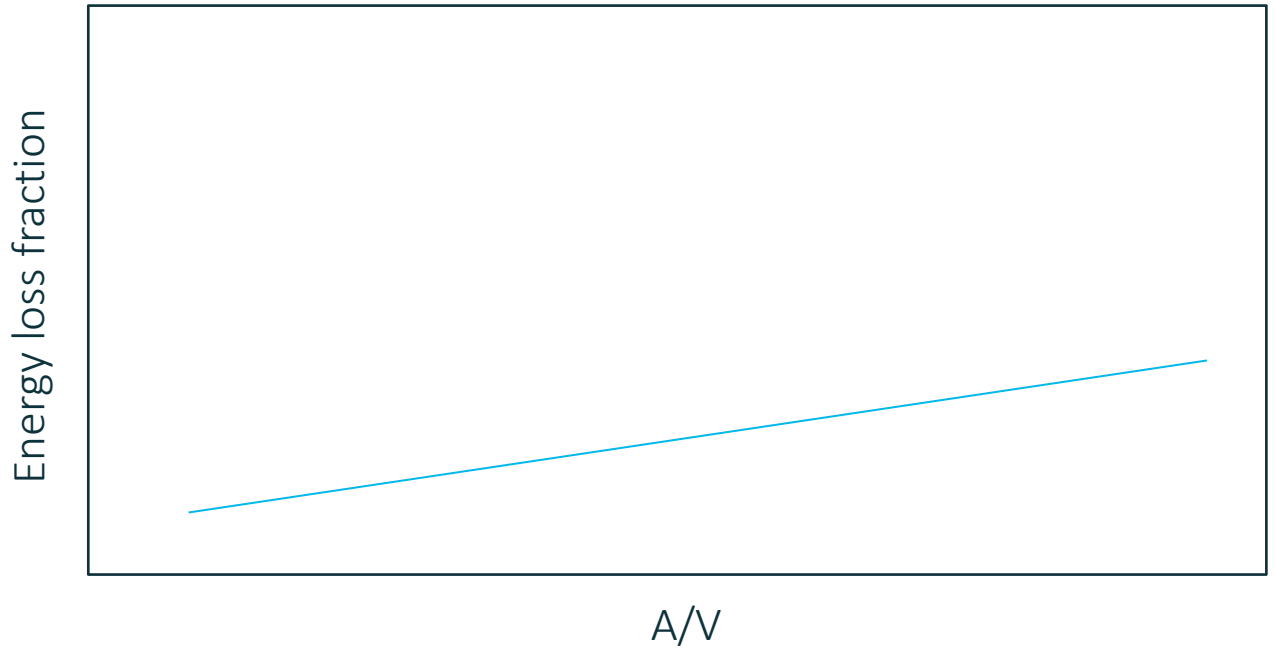
# LT-ATES: Conduction

Geometry:

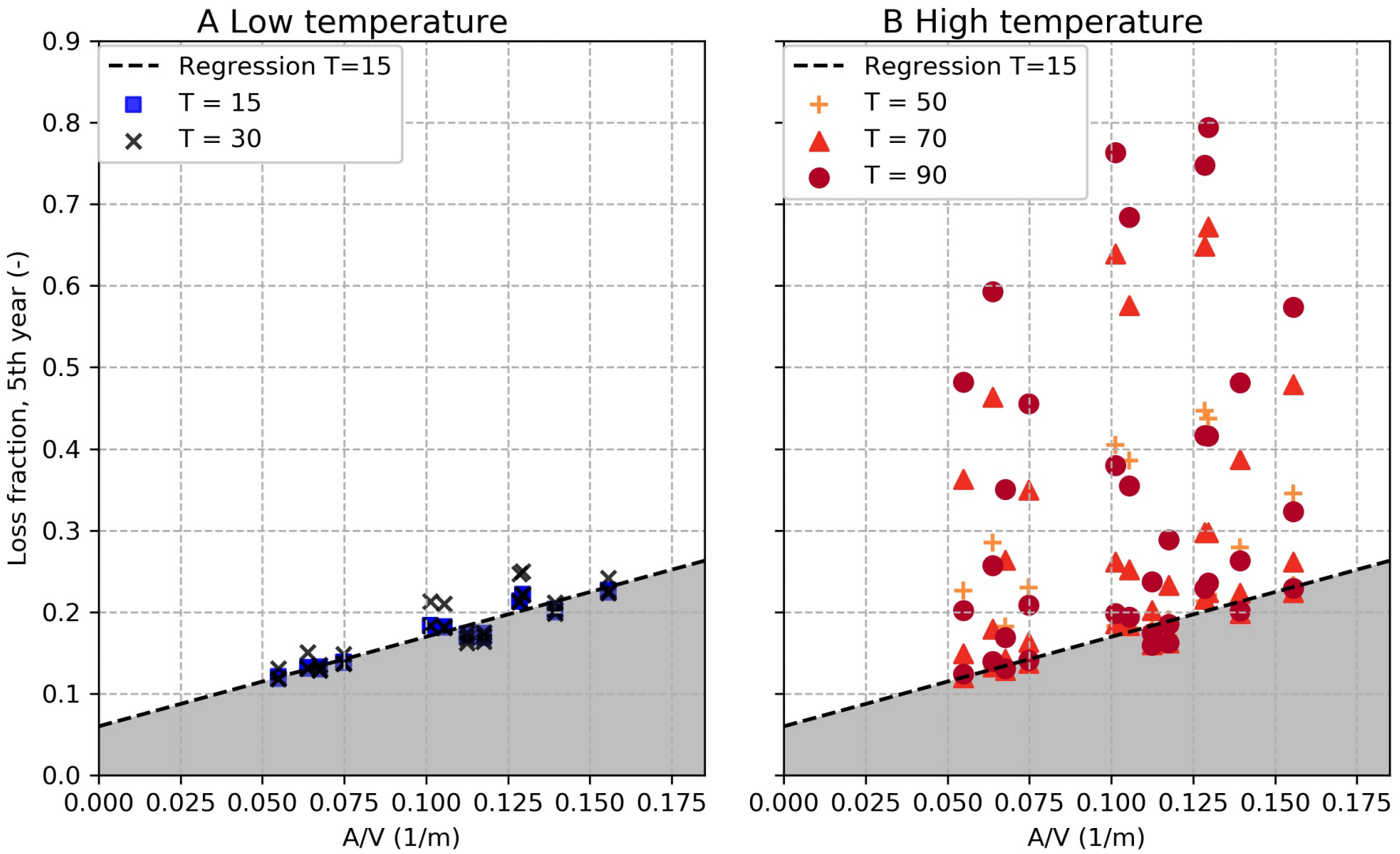
A/V = AREA / VOLUME

Optimal at $L/R_{th} = 2$

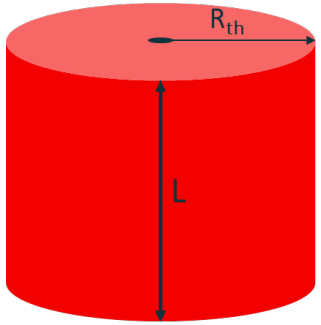


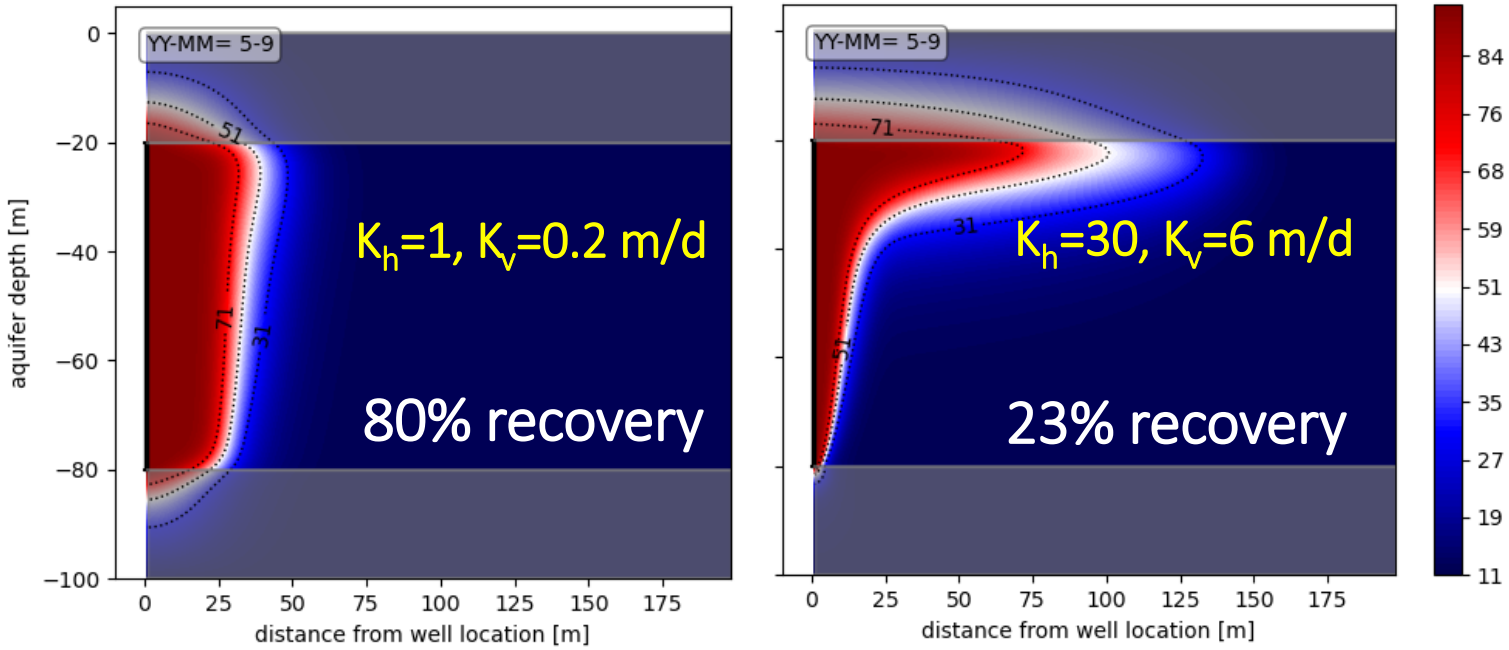



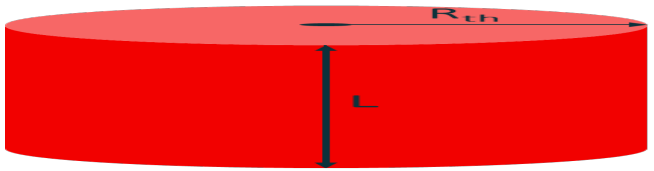

Bloemendal, M., & Hartog, N. (2018). Analysis of the impact of storage conditions on the thermal recovery efficiency of low-temperature ATES systems. *Geothermics, 17, 306-319. doi:10.1016/j.geothermics.2017.10.009*

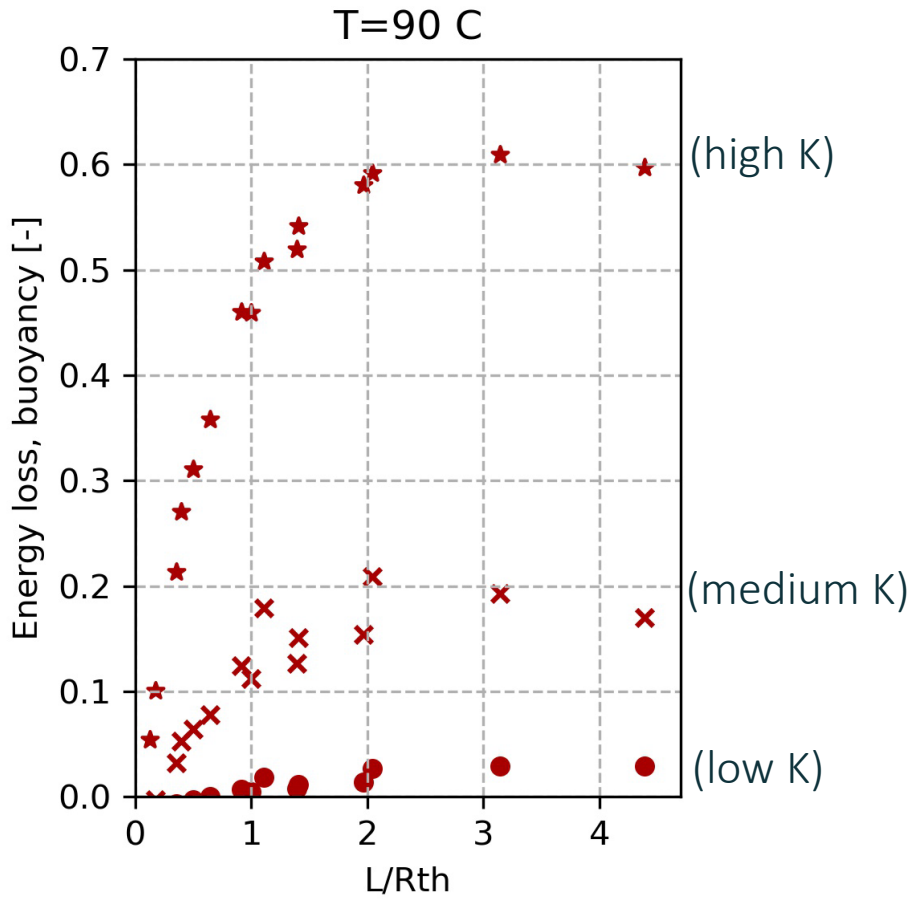

A Low temperature
Regression T=15
T = 15
T = 30
Loss fraction, 5th year (-)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.000 0.025 0.050 0.075 0.100 0.125 0.150 0.175
A/V (1/m)
B High temperature
Regression T=15
T = 50
T = 70
T = 90
0.000 0.025 0.050 0.075 0.100 0.125 0.150 0.175
A/V (1/m)

# HT-ATES: +Buoyancy

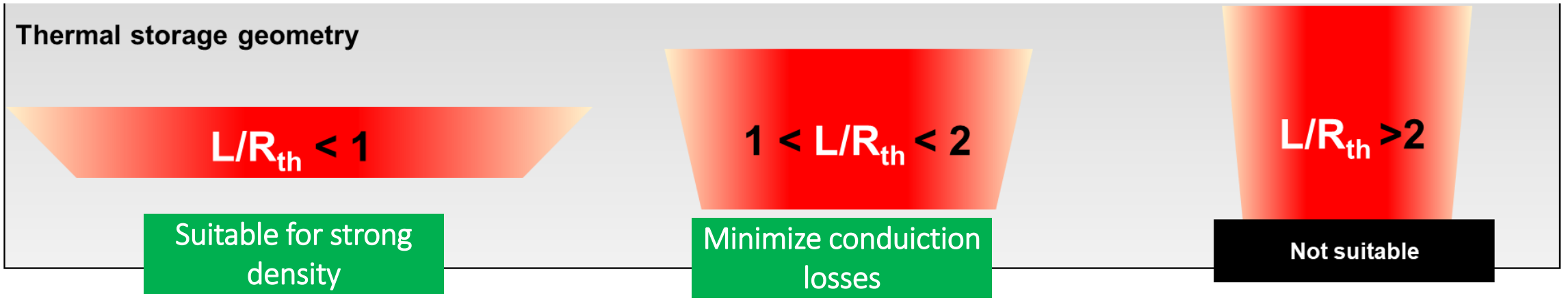


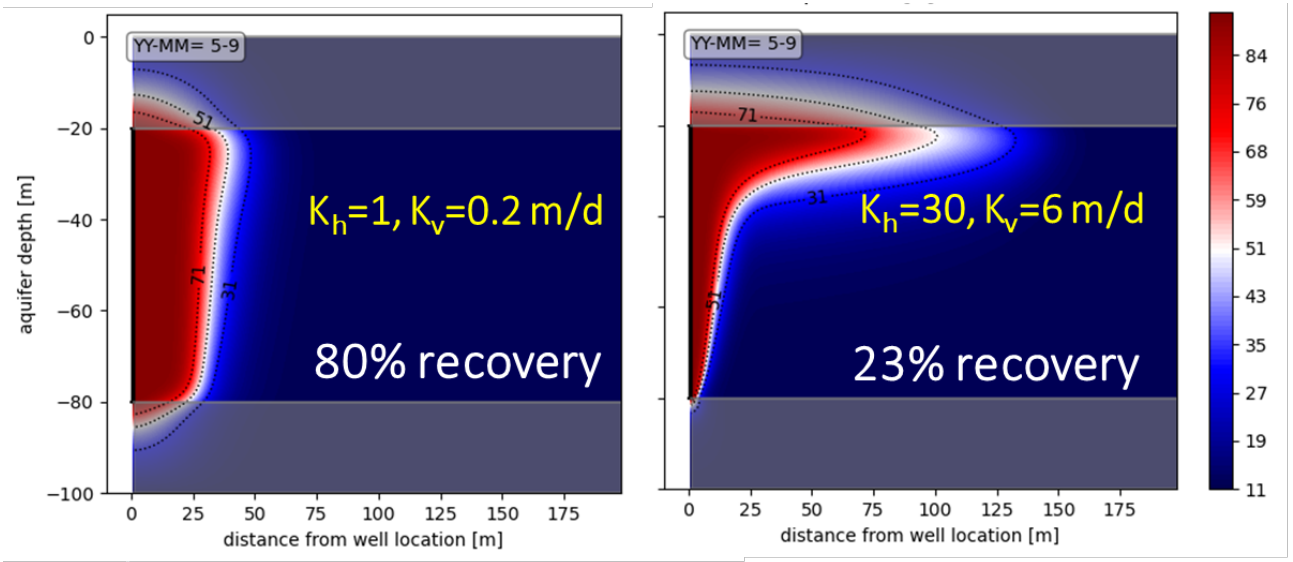



# Impact of storage geometry

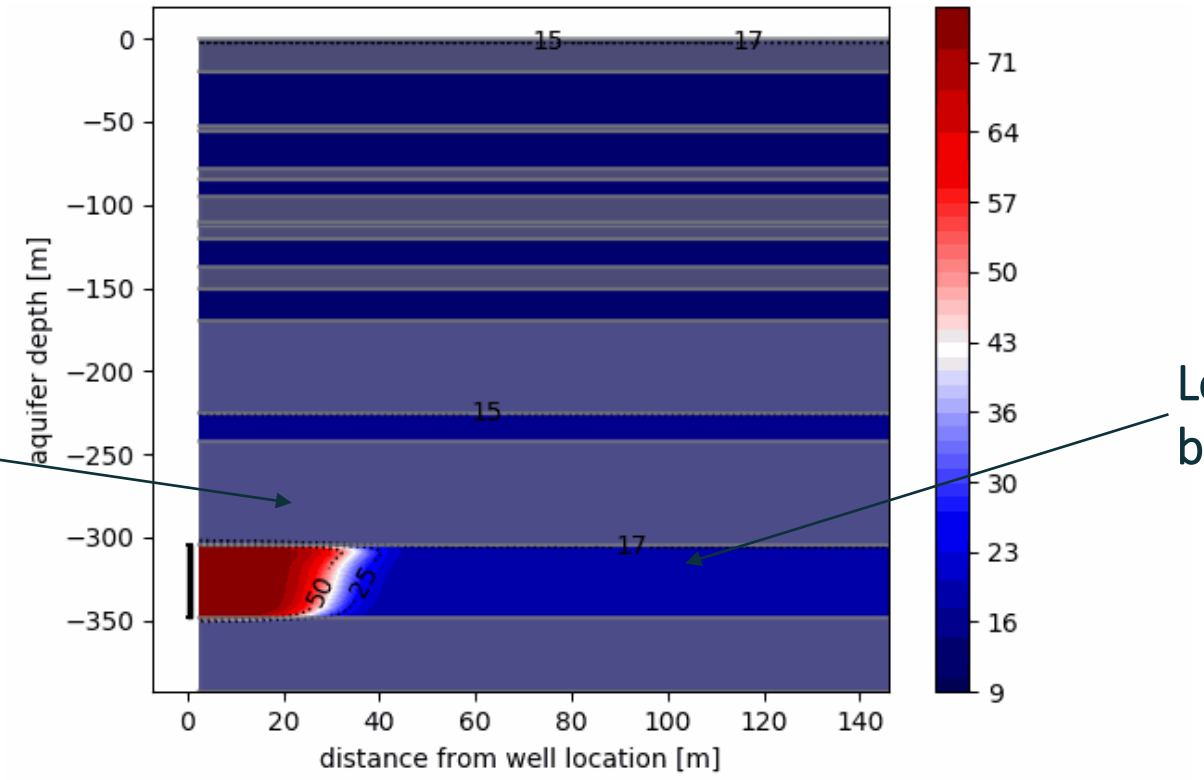



Hydraulic conductivity of the aquifer ?!

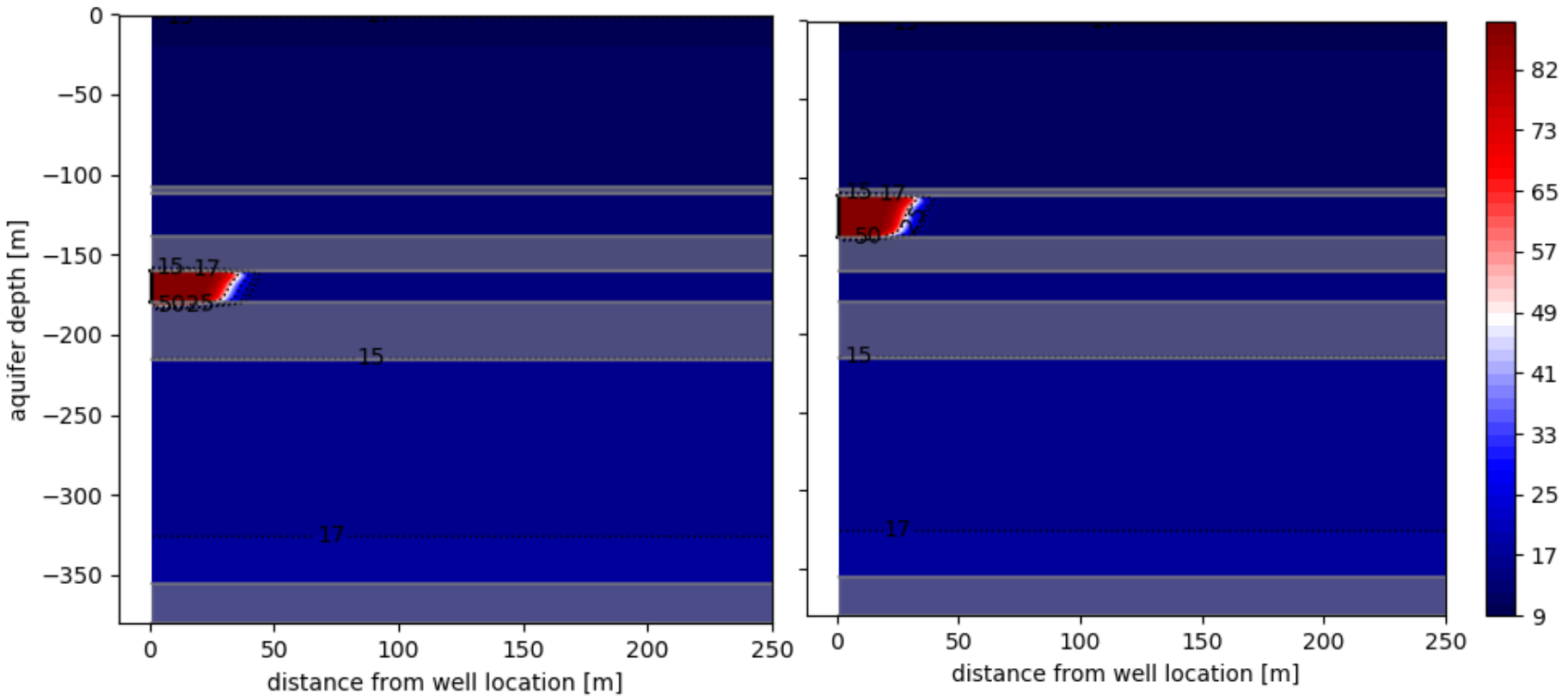
# Energy loss… thermal impact

Conduction into clay layer



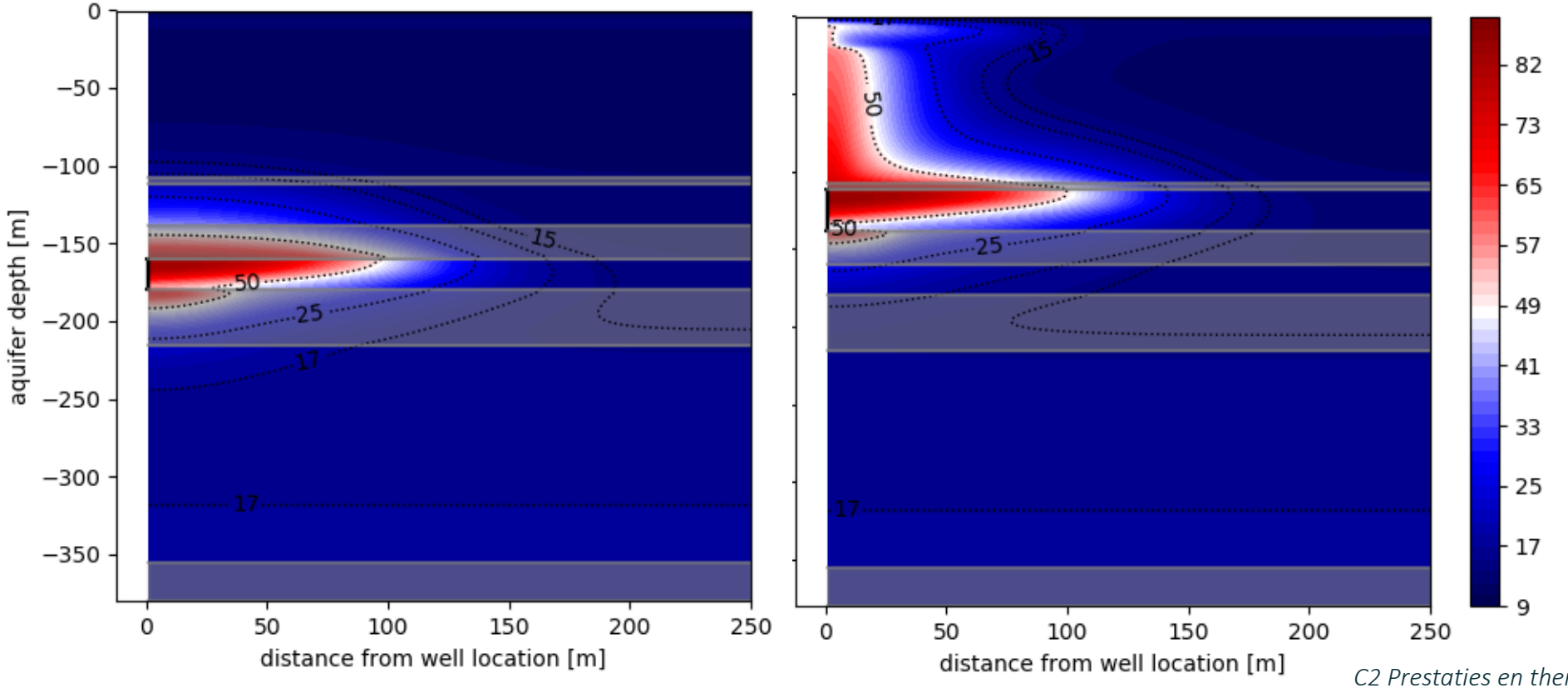

Loss due to buoyancy

# Thermal impact – year 1



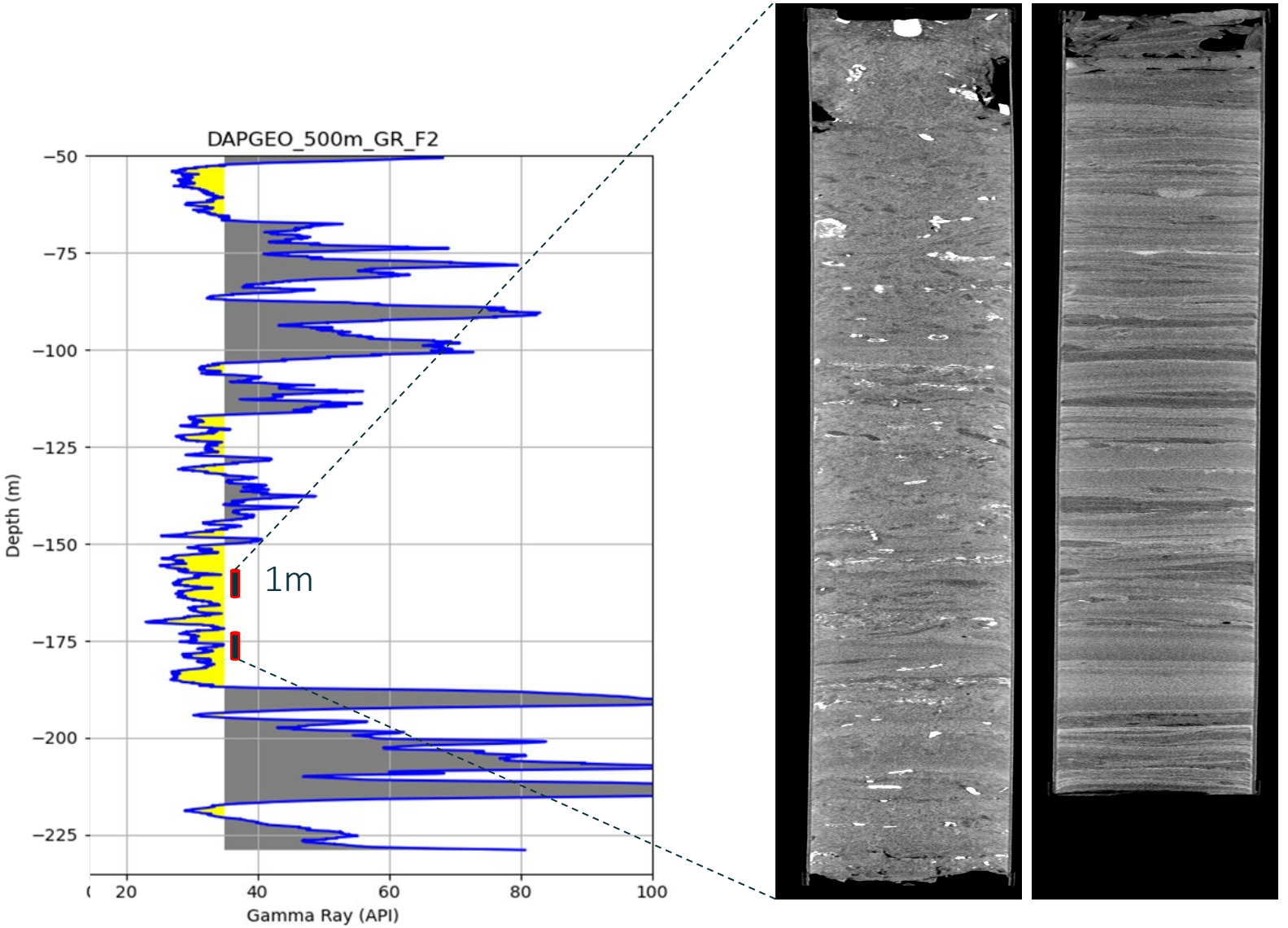
# Thermal impact – year 50

Hydraulic conductivity of the aquifer ?! + surroundings!

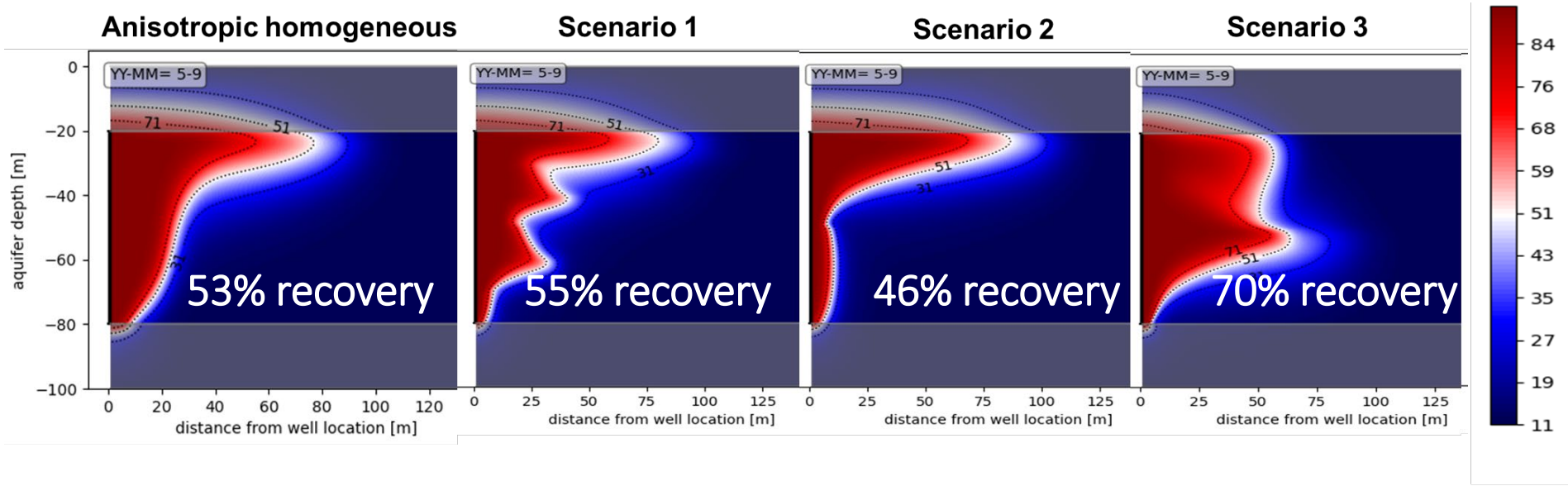



*C2 Prestaties en thermische effecten van ondergrondse warmteopslagsystemen | https://www.warmingup.info/documenten/window-fase-1---c2---prestaties-en-thermische-effecten.pdf*

# Subsurface is heterogeneous at multiple scales



# Impact of heterogeneity



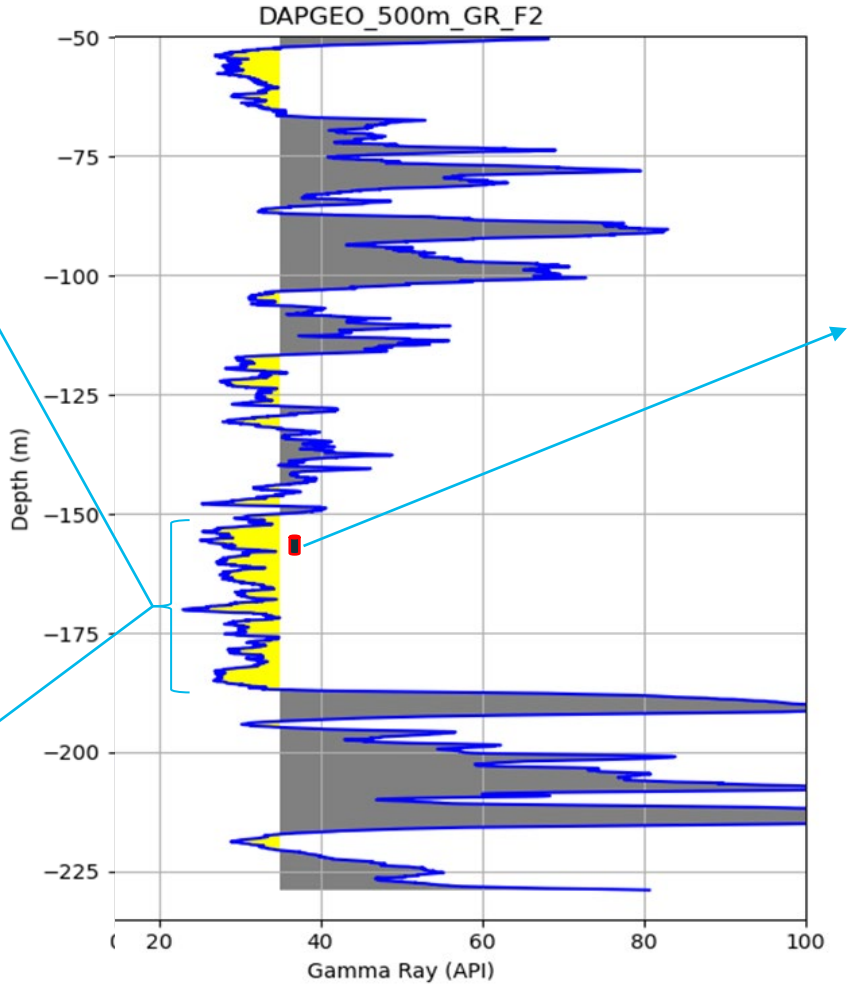

→Hydraulic conductivity of aquifer and surroundings

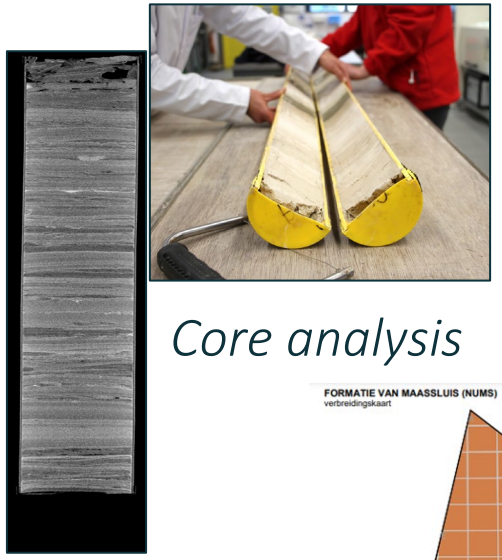
→At large and small scale

# Fieldwork: determine subsurface properties

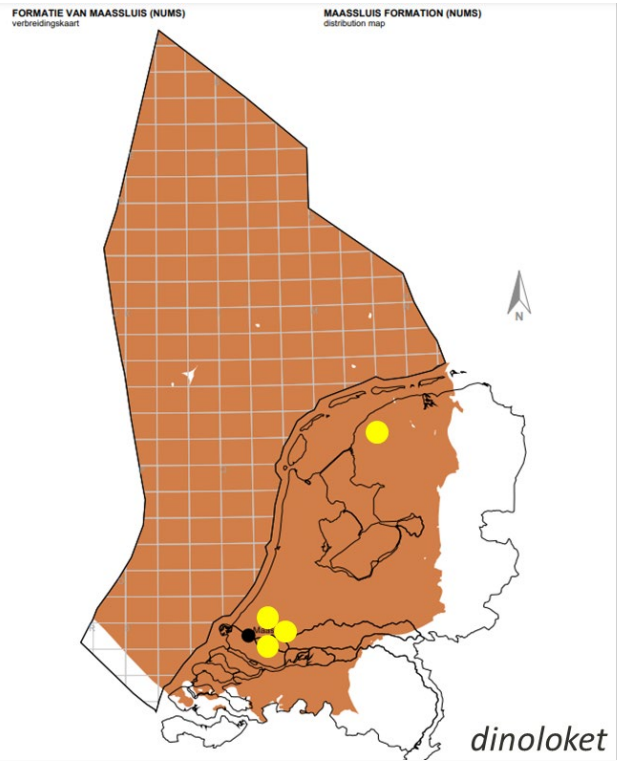
## Cuttings

## Logging

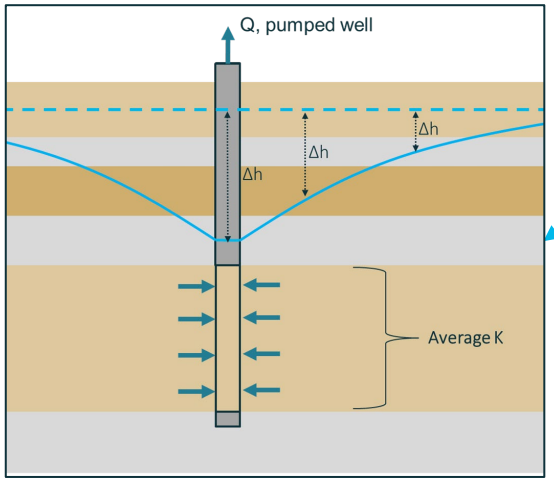


## Core analysis

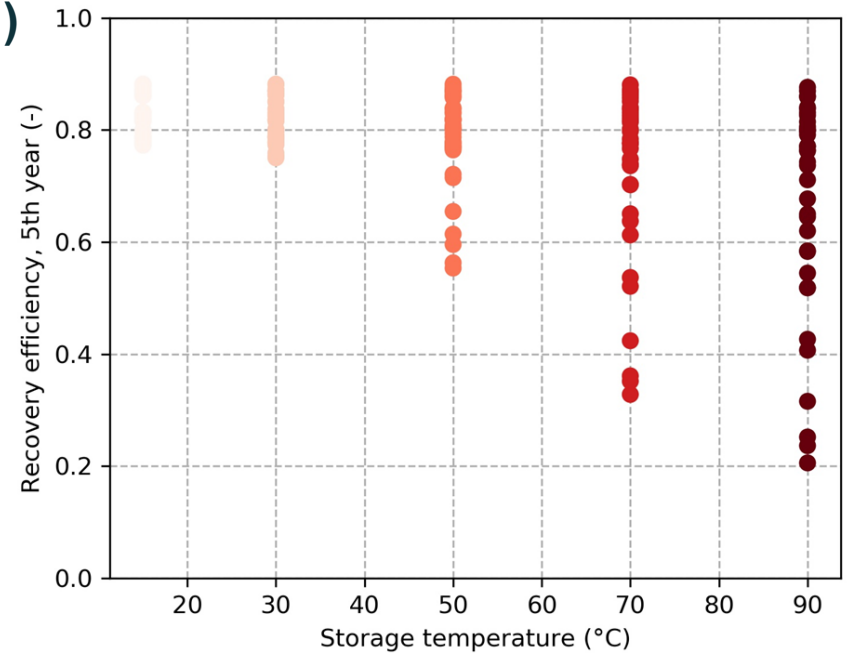



## Pumping test

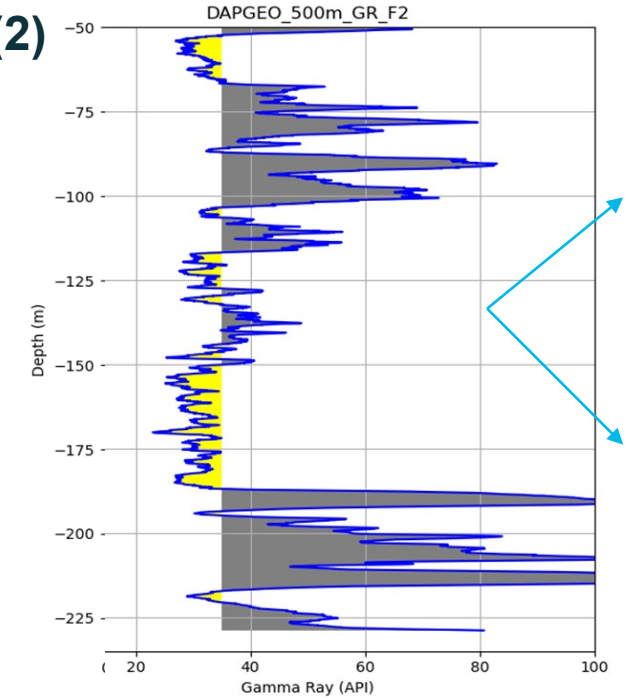


# Conclusions

(1)




(2)




Recovery efficiency

Thermal Impact

→ Current research: how to determine subsurface properties effectively and efficiently?

WARMING UP

7 March 2023

# Efficient and sustainable subsurface heat storage systems

*insight and lessons learned from the WarmingUP project*

KWR TU Delft

**Stijn Beernink,** Martin Bloemendal, Niels Hartog, Phil Vardon, Auke Barnhoorn